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Investigation of Mechanical Properties of theAluminium Extrusion Steel Mould with Nitriding and Ceramic Coating (CrN)

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Abstract: *Surface treatment is technically and economically advantage method which aimed at improving the surface of materials. This study involve the comparative analysis between the extrusion steel mouldswere coated with nitriding and ceramic coating. The AISI2344 steel was heatedat 520 ^{0}C withammonia gas (NH_3)and the diffusion temperature was kept at 520 °Cfor 360 minutes, followed by cooling at 80 °C and remaining about120 minutes. Finally its completed nitrided process. Ceramic coating process also was performed PVD methodwith chromium nitride (CrN). Its performed 7-10 micron multi layer thickness. The microstructure, elemental composition, hardness and surface rougness analysis was performedfor all samples. Its obtained that microstructure is a nonuniform with nitriding in the SEM analysis.The hardness value was obtained 918 $HV_{0.2}$ for sample with nitriding. This value was obtained 357 HV_1 for sample with ceramic coating.Also the surface rougness has a lower Ra value for ceramic coating.When this Ra value is respectively 0.051 µm and 1.481 µm for ceramic coating and nitriding.*

PACS/topics:*steel mould, coating/ceramic coating, microstructure, hardness, surface rougness*

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I. INTRODUCTİON

Surface coating is the most effective method applied to improve the durability of materials in different environmental conditions. Surface coating processes of production equipment in a production process aims to extend the service life, improve the product surface quality and increase the production rate [1]While the machine equipment performs their functionality, the surfaces of the parts are exposed to higher stress and higher abrasive forces than their inner parts. When these stresses and forces exceed the surface strength limit of the material, stress cracks begin on the material surface [2].Extending the life of the equipment used in order to ensure the efficiency as well as the functionality of the equipment is one of the important points. There is great interest in the production of advanced materials for technological uses. In this context, coatings play a critical role in protecting the metal form from stress and corrosion that may occur. Coatings alone have become part of the corrosion control strategy. Theoretically, coatings can be applied by various methods to alter or prevent the corrosion reaction. Various traditional methods such as carburizing, nitriding, electroplating have been used as protection tools for centuries [3].Over the last two decades, new coating deposition techniques offer a wide variety of possibilities that can be adapted for different materials and structures. In particular, the physical vapor deposition (PVD) technique enables thin coating of several micrometers from room temperature to high temperature range. The development of hard protection coatings started with the discovery of chemical vapor deposition (CVD) and physical vapor deposition (PVD) technique. Also Nitride-based hard compound and ceramic coatings find wide application area with various PVD processes. In particular the physical vapor deposition (PVD) technique enables thin coating of several micrometers from room temperature to high temperature range [4]. Physical vapor deposition (PVD) technique is based on the removal of atoms from the surface by evaporating a solid source under vacuum or transforming it into atomic form and depositing atomically or ionically on the surface of the substrate to be coated [5].Nitriding is a surface treatment process. As a result of the diffusion of nitrogen to the steel surface, a hard layer with high wear resistance is formed on the surface. The treatment which increase to fatique strength and corrosion resistance provide to an incorporation of nitrogen into the surface of steel. Also ceramics are inorganic nonmetallic components. When inorganic coatings are applied to metals or other materials. They change their properties such as wear resistance, erosion, shock, oxidation, corrosion, chemical reaction, smoothness, heat transfer by radiation and conduction, electrical resistance, magnetic properties, thermoionic performance, thermal insulation [6].

II. MATERİALS AND EQUİPMENT

2.1. Materials and methods

The process flow diagram is organized in the form of turning, milling and grinding respectively. The steel was first turned into a lathe by cutting the front/back sides of the mill and the milling process was completed with the threading process. Finally the production of the mold is completed by grinding of the outer corner and the grinding of the bearings. The chemical composition of the extrusion molds produced from steels is shown in Table 1.

Table 1. Chemical compositions of 2344 steel

	O%	%Fe	C%	%Cr	%Cu	Si%	V%	%Zn	%Mo
2344	15.43	40.84	8.26	2.64	18.03	0.48	0.47	13.23	0.62

2.2. Coating Process

Two different coating process was performed with nitriding and ceramic coatingwhich chromium nitride in this study. The AISI 2344 steel was heatedat 520 ^{0}C withammonia gas (NH_3) and the diffusion temperature was kept at 520 °C for 360 minutes followed by cooling at 80 °C and remaining about120 minutes. Ceramic coating process also was performed PVD method with chromium nitride (CrN). Its performed 7-10 micron multi layer thickness. Table 2 shows method of coating process.

Table 2. Coating process of 2344 steel

Material	Method
2344 Steel	Gas Nitriding
2344 Steel	PVD

2.3. Metallographic Process

Heat treated extrusion mold samples were made ready for microstructure investigation by standard metallographic methods (mounting, grinding, polishing) and then etching process was conducted to the samples by using 2% nital solution.

2.4. Mechanical Process

2.4.1. Hardness Tests

Hardness values were measured by taking sections from the extrusion molds. Macro and micro hardness measurements were measured at different load hardness tester. Hardness measurements were made from the surface to the center.

2.4.2. Rougness Tests

Rougness surface test was performed with Ra and Rz value for extrusion mould samples.Surtfest SJ-210 test device was used in the rougness test.

2.5. SEM/EDS Analysis

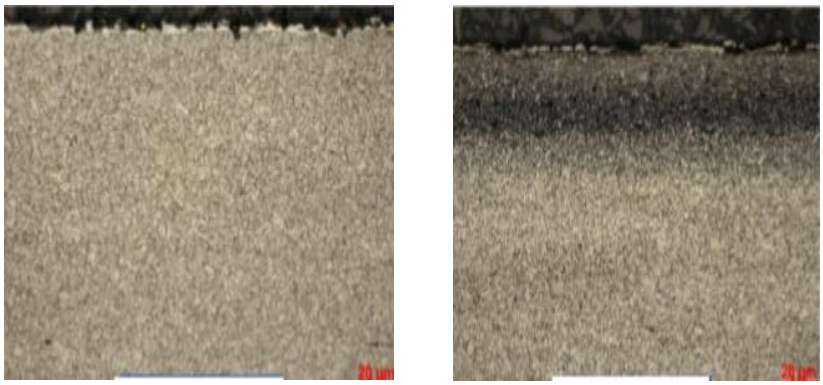
SEM and EDS analysis were performed for extrusion mould samples. Tescan Vega test device was used in the SEM and EDS analysis.

III. RESULTS AND DİSCUCCİONS

3.1. Microstructure

3.1.1. Optic Analysis

Figure 1 shows the metallographic structure of the AISI 2344 Steel without coating and nitriding.Also it can be observed the film layer of the sample with nitriding. The surface structure of ceramic coating also analyzed with SEM analysis.



a) **b)**

Figure 1. Surface appearance of samples a) raw material, b) nitriding

Figure 2 shows film layer which occurs after nitriding process. The film layer thickness was measured 200.4 µm.Film layer thickness play a critical role in terms of corrosion resistance and wear resistance. Also the microstructure was obtained that provides to increase mechanical properties with this film layer .

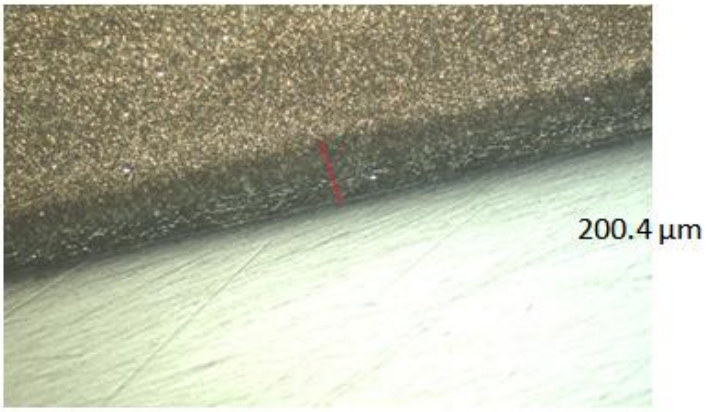
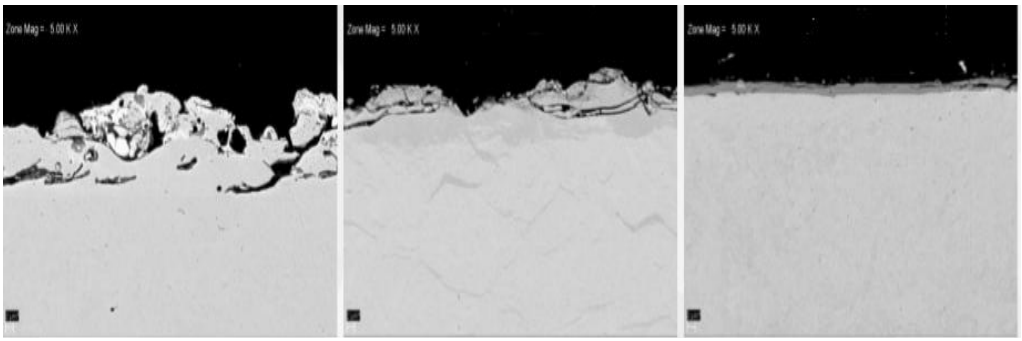


Figure 2. The film layer thickness after nitriding process

3.1.2. SEM Analysis

Figure 3shows the metallographic structure of the AISI 2344 Steelwithout coating, nitriding and also ceramic coating respectively.AISI 2344 Steel has a pores structure before the coating. Also its observed that the film layer of the sample with nitriding and ceramic coating. However the nonuniform structure of the sample with nitriding was observed in the SEM analysis. Also Figure 4 detailed shows microstructure analyses.



a) **b)** **c)**

Figure 3. Surface appearance a) AISI 2344 Steel b) nitriding c)ceramic coating

The film layer that should be formed on the surface during nitriding.This film is the most nitrogen-rich and functional part.It is the part in contact with the aluminum material drawn through the mold.It is important that this film is homogeneous (uniform) and without cracks (damage).

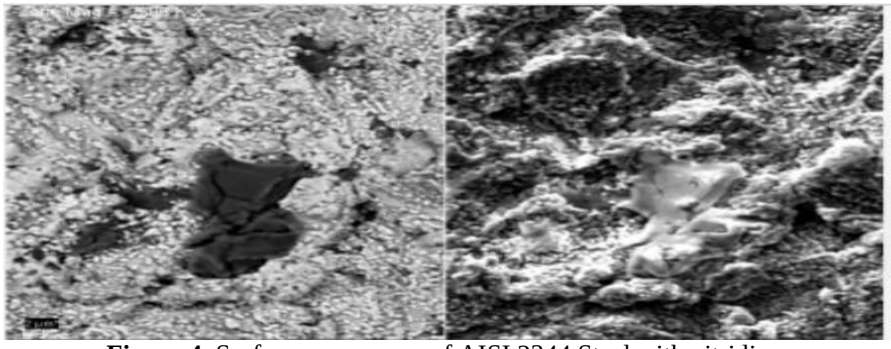
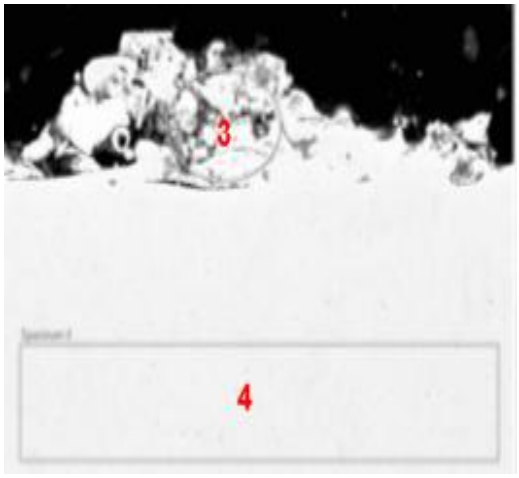


Figure 4. Surface appearance of AISI 2344 Steel with nitriding

SEM analyzes were conducted to determination of coating ability as a result of the coating prosess. Figure 4 shows that nonuniform mechanisms were determined on the base of SEM images. It is concluded that wear modes can be detected on all fracture surfaces with nitriding.

3.1.3. EDS Analysis

EDS analysis was performed for all samples because of determination of elemental composition distribution for all surface. Its observed that Cr and N elements dominant than other elements when the ceramic coating sample was investigated. Also it can be clearly observed that ceramic coating sample exhibits uniform structure than others. Figure 5 shows SEM EDS analysis for all samples.



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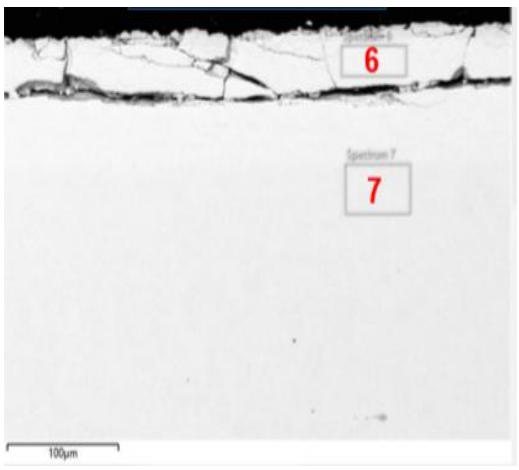
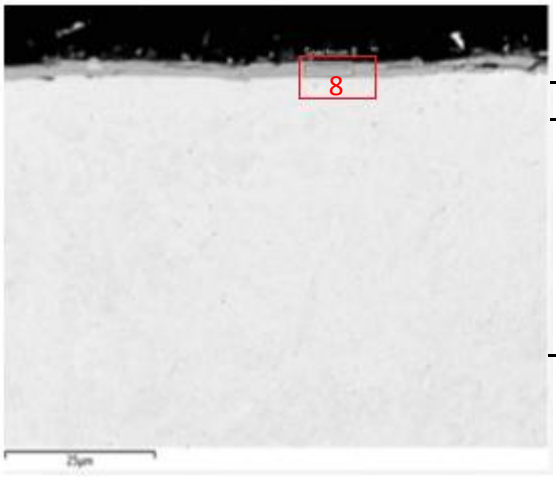
Spectrum 3		**Spectrum 4**	
Element	**Weight %**	**Element**	**Weight %**
O	7.73	Fe	91.19
Fe	34.09	Cr	5.37
Cu	39.73	Si	0.76
Zn	8.90	V	0.82
Cr	2.90	C	1.86
C	6.66	Total	100.00
Total	100.00		



Spectrum 6		**Spectrum 7**	
Element	**Weight %**	**Element**	**Weight %**
Fe	86.78	Fe	88.94
Cr	5.19	Cr	5.07
N	3.15	C	2.73
Si	0.87	Si	0.92
V	0.69	V	0.78
C	2.01	Mo	1.55
Mo	1.30	Total	100.00
Total	100.00		



Spectrum 8	
Element	**Weight %**
C	9.24
N	21.49
Cr	65.98
Fe	1.24
O	2.04
Total	100.00

Figure 5. SEM EDS analysis a) raw material b) nitriding c) ceramic coating

3.2. Mechanical Tests
3.2.1. Hardness Test

Hardness test was performed for all samples. HRC hardness value was obtained for raw material and nitriding sample also HV hardness value was obtained for ceramic coating. Figure 6, Figure 7 and Figure 8 showhardness value for each samples.

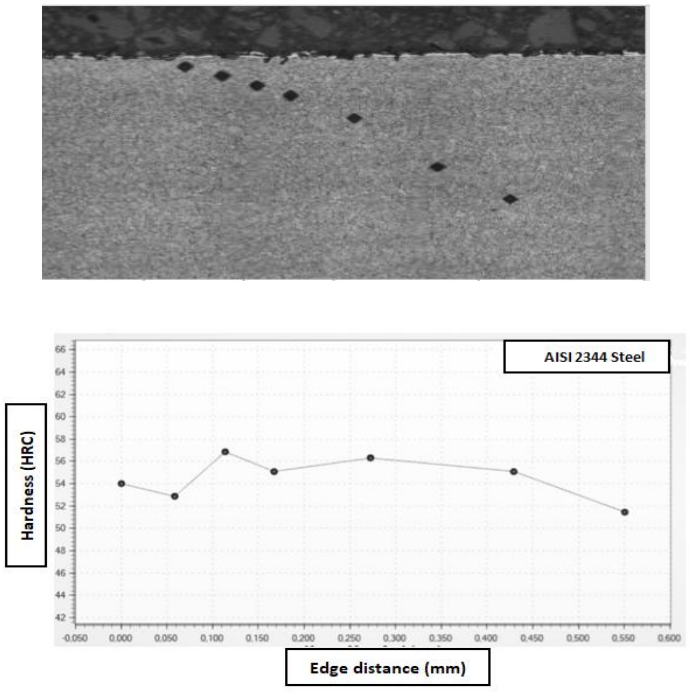


Figure 6. Hardness test analysis of AISI 2344 Steel

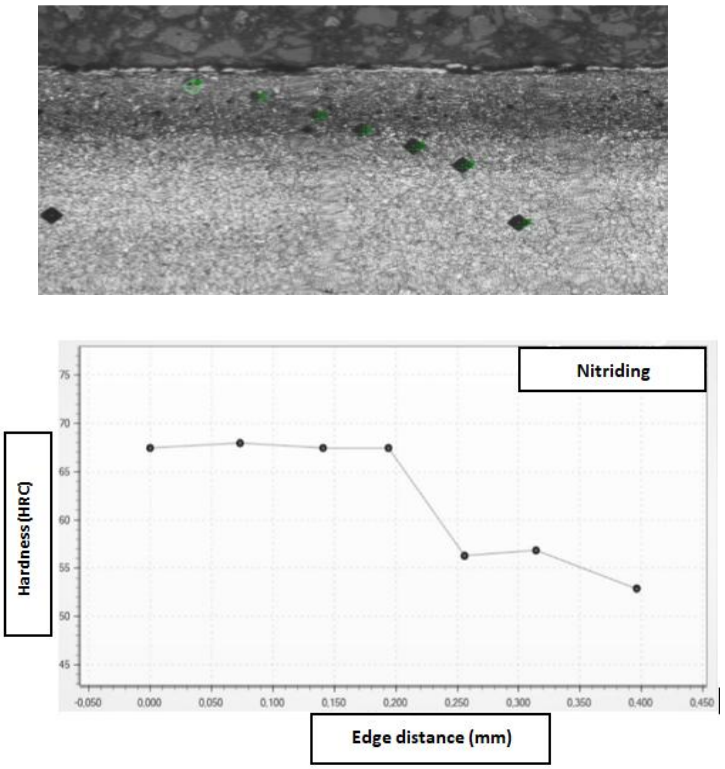


Figure 7. Hardness test analysis of AISI 2344 Steel with nitriding

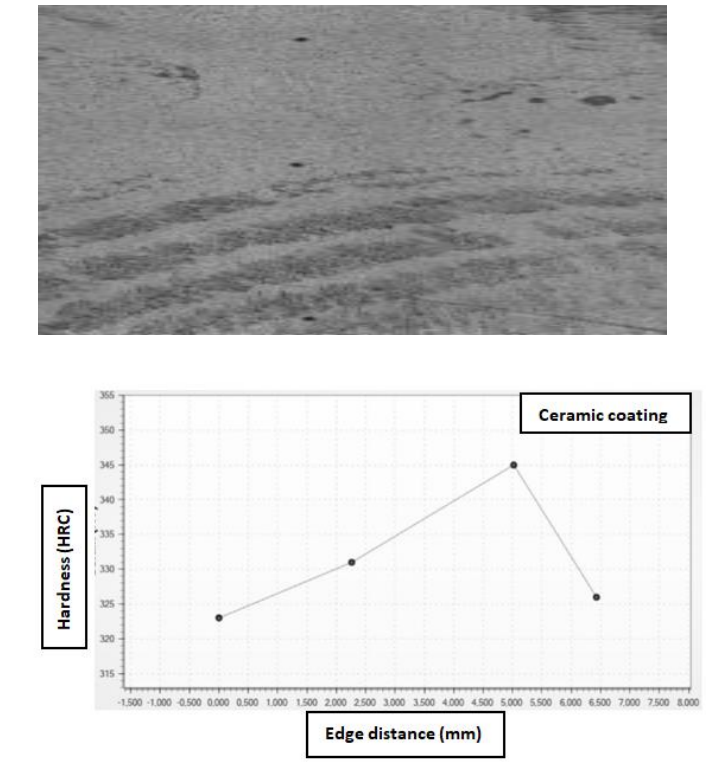


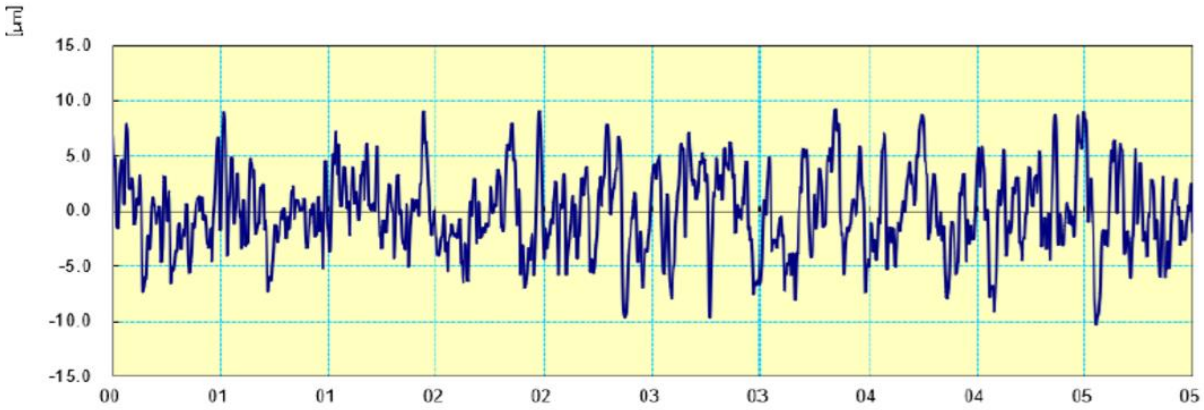
Figure 8. Hardness test analysis of AISI 2344 Steel with ceramic coating

3.2.2. RougnessTest

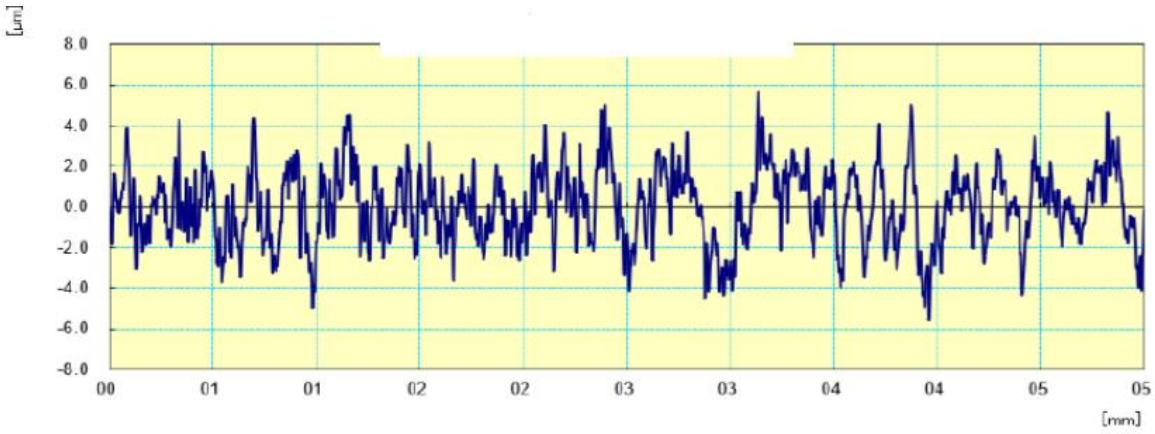
Surface rougness analyses shows in Figure 7 was performed all samples. Its observed that the surface rougness are different each samples. Also its obtained that the sample which is ceramic coating has a lower surface rougness. Table 3 shows comparative analysis of surface rougness for each samples. Figure 9 shows surface rougness tests.

Table 3. Surface rougness analysis of 2344 steelwith different coating.

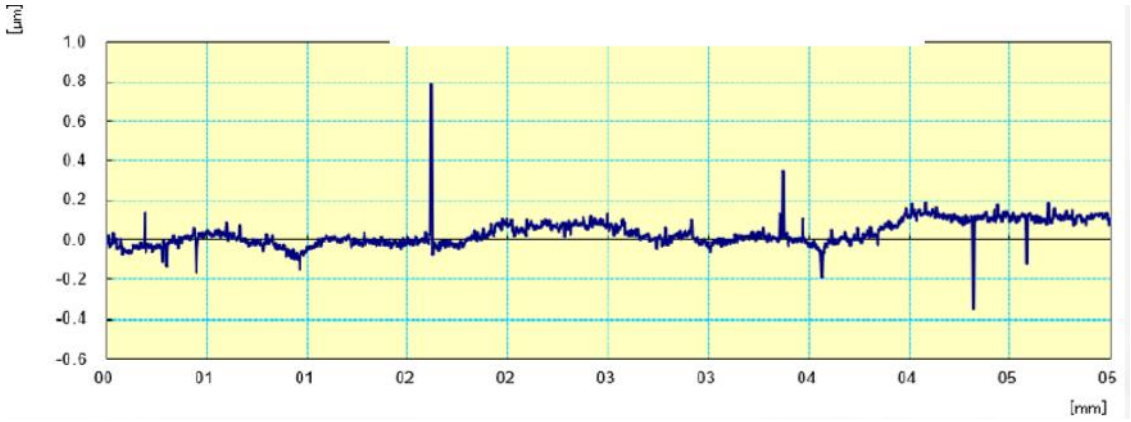
	Raw material	Nitriding	Ceramic Coating
Ra (µm)	2.911 µm	1.481 µm	0.051 µm
Rz	19.012 µm	10.640 µm	0.829 µm
RPc	88.46 /cm	79.29 /cm	110 / cm



a)



b)



c)

Figure 9. Surface rougness analysis a) raw material b) nitriding c) ceramic coating

IV. CONCLUSİONS

The aimed of the performance different coating process for aluminium extrusion steel mould in this study.Its observed that some noninuform structure with nitriding process. Also maximum hardness value was obtained in coating process.The surface rougness of ceramic coating sample has a lower Ra value.Many researchers have conducted experimental studies on the erosion of PVD Nitride coating.Deng Jianxin et al. (2012) conducted CrN, TiN, CrAIN and TiAIN coating trials with the PVD method on the basis of wear resistance and comparative analyzes were made.Considering the coatings made according to the erosion test results, the TiAlN coating exhibited the lowest abrasion depth under the same conditions, while the CrN coating exhibited the highest wear depth. Also the mechanical properties is more important than surface rougness for aluminium extrusion steel mould.Also its observed that nitriding process is more suitable for AISI 2344 steel which is used as a extrusion mould raw material in terms of mechanical properties that obtained in this study.Therefore we aimed to investigated nitriding process with different% N value as a continuation of this study.

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